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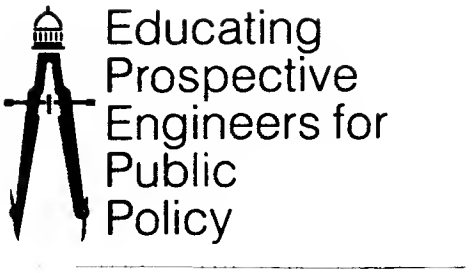
CELLULAR RADIO

THE NEW MOBILE PHONE TECHNOLOGY

A description of the development of cellular radio, a system which utilizes small geographic units called "cells" with low power radio frequency transmissions instead of the high-powered wide-range transmissions currently used in most mobile communications. The cellular radio system developed for the Chicago area is traced through its inception at Bell Laboratories, licensing by the FCC, and commercial service testing.

Susan Word Longwell

Washington Internships for Students of Engineering (WISE) Program



CELLULAR RADIO --

THE NEW MOBILE PHONE TECHNOLOGY

by

Susan Word Longwell[1]

March 1984

Prepared as part of the 1982 Washington Internships for Students of Engineering (WISE) Program under the supervision of Dr. Karl Willenbrock[2], 1982 WISE Faculty-Member-in-Residence; revised and edited by Robin Chikos[3] and Dr. Barry Hyman. This work was supported by NSF Grant SED 7918984. All opinions presented are those of the author and do not in any way represent those of NSF, the author's institution, or of other individuals or institutions referred to in the text.

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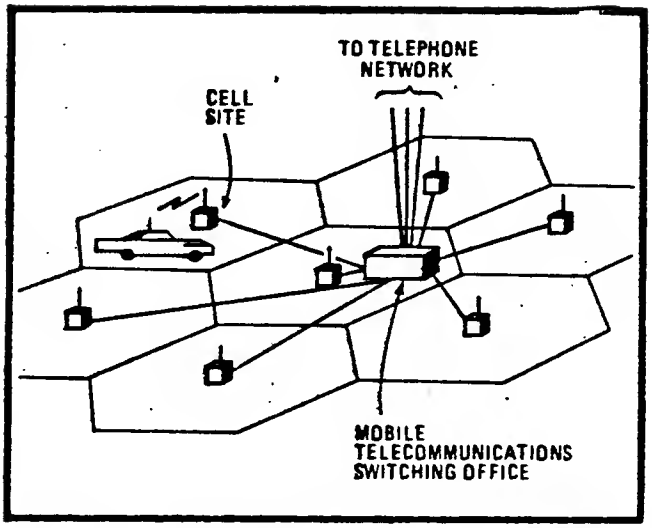
PART A: WHAT IS CELLULAR RADIO?

Cellular radio is a relatively new technology designed to expand mobile telephone service. Currently, the commercial mobile phone service is of poor quality and accommodates very few customers. For example, in New York City (population 8,000,000 plus) the approximately 700 customers who have mobile phones experience poor service due to the trouble of finding an open channel. In fact, the chance of completing a call on the first attempt is well below 50%. Moveover, the prestige associated with ownership of a mobile phone indicates the difficulty of obtaining what service is available. Waiting lists for mobile phone service include several thousand applicants and entail a six-to seven-year wait. The introduction of cellular technology will revolutionize the market by increasing the number of users nearly 100-fold while providing those users with high quality service. Quoting Charles Ferris (Federal Communications Commission Chairman from 1977 to 1981), "I had a mobile phone in my car when I was a commissioner, and the quality was so poor, I couldn't really use it. But the cellular phones I've tried from the Chicago test are so good, I've become a convert."

The technical differences between traditional and cellular systems are immense. Traditional systems have an allocation of 23 channels (30KHz spacing) per area and use a single, high-powered base station to serve an entire city. Only one call can be handled per channel. When a channel is being used in a particular area, it cannot be reused within a radius approaching 75 miles due to cochannel interference associated with the high power signal levels.

A cellular approach divides a service area into small units called "cells." Each cell is served by low-powered transmitters, separate receivers, and a control system which together constitute a "cell-site." Every cell site is connected to a Mobile Telephone Switching Office (MTSO) using conventional overland telephone lines. The MTSO is in turn connected to the main telephone network. Each cell serves moble customers when their vehicles are within a particular cell. As a vehicle moves to another cell, the call is transferred automatically or "handed-off" to the next cell site's control. The hand-off process takes approximately one-twentieth of a second and is usually unnoticeable to the customer. The main advantage of a cellular system is that the assigned radio frequency channels may be reused in other cells sufficiently far apart. See Exhibit A-1 for a cellular structure overview and a cell site sketch.



1. Cells. Through frequency reuse, a cellular mobile-telephone system in one coverage area can handle many more calls simultaneously than the number of allocated frequency channels. A hexagonal cell is the most efficient, requiring the fewest transmitter sites.

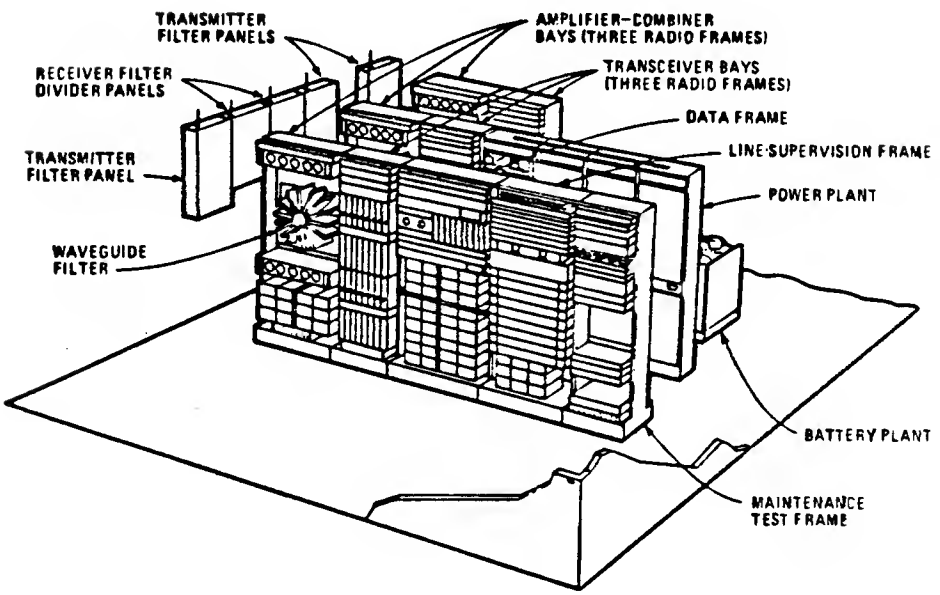


Exhibit A-1, Structure Overview and Cell Site Sketch (reprint by permission from May 24, 1979 issue of Electronics, Copyright (c) 1979, McGraw-Hill, Inc., All rights reserved.)

PART B: WHAT MAKES CELLULAR RADIO POSSIBLE?

Technical Development

It may well be asked why a cellular system approach was not implemented sooner. The answer is the complicated switching and control problems involved in the hand-off process. Three technologies make a cellular system economically and technically viable: 1) a central control computer with stored programs and fast switching system, 2) large scale integrated custom circuits, and 3) microprocessors. These technologies are explored further in this case.

Frank Blecher, Director of the Mobile Communications Laboratory since October 1974 was responsible for the technical development of the cellular radio program at Bell Telephone Laboratories. Frank received his BSEE, MSEE, and DEE degrees in 1949, 1950, and 1955, respectively, all from the Polytechnic Institute of Brooklyn, and has been with Bell Telephone Laboratories since 1952. As the Director, Frank was responsible for all mobile communication development work, including research and development, planning, and carrying out trials in both Chicago and New Jersey. (A cellular test bed was set up in Newark, N.J. to evaluate the radio's technical performance. The New Jersey tests are not discussed in detail in this case. Rather, the focus of this case is on the Chicago trial and its ensuing developments.)

Securing FCC Approval

Aside from the technical developments, many non-technical aspects were also involved in introducing cellular technology from its inception at Bell Laboratories to the allocation of radio frequencies by the Federal Communications Commission (FCC). The FCC was created by Congress in 1934. It still functions within the original basic framework, even though the technologies under its jurisdiction have dramatically changed to include television, satellite systems, cable systems, computer aided data transmission systems and cellular radio. On any specific issue, the FCC proposes allocations and regulations of frequency space and, when appropriate, conducts public hearings allowing interested parties the opportunity to air arguments both pro and con.

The time lapse between opening the official FCC file, called FCC Docket No. 18262, in 1968 and allocation of frequencies for cellular developmental systems in 1975 is indicative of the problems in launching cellular radio. Three distinct aspects of this story will be examined: 1) problems the FCC has with changing frequency allocations, proposing regulations and licensing; 2) protests of users whose frequency allocations are affected; and 3) Bell's argument as to how much frequency space is necessary and who should receive licensing.

For 6 years, the FCC had studied where to allocate space for cellular radio. Then, in 1974 two blocks of 20MHz each were assigned for cellular usage, the 825-845MHz and 870-890MHz regions, with licenses available to telephone companies.

The FCC was flooded with requests for public hearings on their proposed allocation. The bands chosen displaced a small number of UHF television channels offering educational programming. Also displaced were some Industrial Science and Medicine (ISM) device allocations, which were moved to reduce interference to cellular systems. Broadcasters, the National Institute of Health, and others protested the expense involved in making those changes. The FCC held its position, as the range of frequencies allocated caused the least displacements possible and were well suited to transmission requirements of cellular radio.

Other complaints centered around licensing of only telephone companies. This ruling brought denunciations against the FCC from many sectors. The FCC had seen telephone companies as the logical supplier of the new mobile phone service, as the Bell System via Bell Labs had the technical expertise to implement a developmental program. Also at this time, Bell representatives petitioned for a larger allocation of 64MHz as they had originally requested in their 1971 proposal to the FCC. The decrease in bandwidth necessitates more frequency reuse, thus more radio spectrum efficiency, but extra costs. Bell representatives claimed the cost increase would approach 50% rather than the 20% increase originally estimated.

After more than a year of hearings and consideration, the FCC issued regulations relative to cellular development programs on March 20, 1975. The 40MHz allocation stood, as the Bell representatives could not substantiate to FCC's satisfaction the necessity of increasing the assigned radio spectrum. The channels assigned remained the same, but provisions for competition with telephone companies were added. Within any service area, a telephone company and a non-wireline* company could be licensed with a 20MHz assignment each. Four allocations of 5MHz each were put in reserve for expanded cellular usage in the future. AT&T was specifically required to completely separate its cellular service from its

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*offering radio communications for public hire excluding telephone companies

wireline service to prevent any cross-subsidizing from occurring. The FCC's requirements for a developmental system license in terms of both required technical characteristics of the proposed system and the contents of the proposals were published in its order of Notice and Inquiry on Docket No. 18262 (Exhibit B-1).

Following these FCC guidelines, Illinois Bell Telephone, in conjunction with AT&T, submitted a new proposal for a developmental system in Chicago in March 1975. The FCC turned down this application for the Chicago development system in 1976. Frank Blecher felt that the FCC rejected the application not for any technical reason, but for political reasons, namely that no other applications had been submitted. According to Blecher, "They had no real technical basis for turning us down." Blecher felt that it was still a good proposal, and hoped that a revised version of the proposal would be submitted in the near furture. After making a few minor changes in their application, in particular cutting back on the bandwidth and reducing the number of cars from 5000 to 2000, Illinois Bell Telephone resubmitted the proposal and remained very patient. But it wasn't until after American Radio/Telephone Service (ARTS) submitted an application that Illinois Bell Telephone was finally granted a license by the FCC in March 1977.

Exhibit B-2 illustrates the chronology of events leading to the Advanced Mobile Phone Service (AMPS) demonstration in Chicago, Illinois. AMPS is a separate subsidiary of the communication giant - American Telephone & Telegraph (AT&T). AMPS has entirely separate records and employees, but access to the research capabilities of Bell Laboratories.

REQUIREMENTS FOR SYSTEM:

1) definitely cellular

2) base transmitters at a minimum RF power for each cell

3) base connections through wirelines and common switching

4) full interconnection with the public telephone network

5) must be able to expand from original 12.5MHz allocation to 40 MHz as needed.

PROPOSALS MUST INCLUDE:

1) technical and operational standards to be tested or developed

2) a time schedule for development

3) report of financial capability at each stage

4) completion of tests no later than January 1, 1979

5) monitoring by FCC with progress report every 90 days

Exhibit B-1, Summary of FCC Requirements for Applications for Developmental System License

1930's early 1940's	Early development work begins on mobile service, proceeds through testing trial stages
1946	First commercial mobile service introduced in St. Louis
1950's 1960's	Mobile service expands nationwide, becomes comparable operationally to regular service but does not compare favorably with quality of regular service; Bell Laboratories begins effort to develop new and better mobile systems
1968	Federal Communications Commission opens Docket No. 18262, focuses attention on mobile service, seeks more efficient systems
1970	FCC conducts extensive investigation of mobile service, finds need to expand and improve service, invites proposals from telecommunications industry on new mobile system
1971	In response to FCC invitation, Bell System files proposals for development of cellular mobile systems
1974-1975	FCC allocates frequencies for cellular systems, opens field to all those interested in developing cellular systems
1975	Illinois Bell Telephone Co. files application with FCC to begin developmental test of high-capacity cellular system in Chicago area
1977	FCC grants Illinois Bell's application for Chicago test. Bell System announces it will proceed with Chicago trial, AT&T announces that Bell Labs has selected three companies to supply mobile sets for Chicago trial
1978	Installation completed at the Chicago cell sites, and hand-offs between cell sites are successfully demonstrated
1979	Tests go into final stage with favorable results expected, data to be studied and plans for future to be evaluated

Exhibit B-2, Chronology of Events

PART C: AMPS BEGINS IN CHICAGO

System Design

With a license issued by the FCC, Illinois Bell and AT&T began cell site and Mobile Telephone Switching Office (MTSO) construction with subsequent equipment installations for the mock-up trial in Chicago. The trial's major functions were to test customer service and marketing. A separate trial was conducted at the cellular Test Bed in Newark, New Jersey to prove the basic technical concept. In the proposal for the Chicago developmental system, a ten-cell configuration covering 2100 square miles was put forth. All locations for cell sites, etc. had been chosen and tentative arrangements made for use. Seven of the cell sites could utilize existing antenna structures, while the other three cells required that antennas and antenna masts be built. For developmental purposes, a single central cell site was used to reduce cost and simplify implementation. In a mature system, one in which all cell sites are located at alternate corners of the hexagonal cells and employ directional antennas, cell sites would be constructed as shown in Exhibit C-1.

Note that frequency reuse would occur in cells with the same number. As service demand grows in an area, a cell may be split into smaller units with lower transmission capabilities to allow for more frequency reuse. See Exhibit C-2 for a realistic cell splitting pattern.

In developmental and mature systems different antenna configurations are used. Each type of configuration will radiate a different antenna pattern. By altering the antenna configuration, the coverage of each cell site can be adjusted. Exhibit C-3 shows the antenna patterns of both omni- and uni-directional antennas.

To avoid changing power distribution in all cells, a new antenna mast was designed to permit lower transmission capabilities, or the coverage range, of a single cell. These new antenna masts, which were utilized in Chicago, consisted of a 100' section and a 50' section. Each section could be used separately, or they could be used in combination to form a 150' antenna. Using a lower antenna height reduces a cell's coverage range, allows more radio frequency reuse, and thus expands service. With all equipment ready for installation, Illinois Bell was faced with a zoning problem which developed at one of the cell sites. Its location had to be changed, delaying its installation. This last cell site was relocated in Roundout, Illinois.

When a mobile unit initiates a call, it sends a request for service and receives a voice channel assignment on one set of data channels called setup channels. When it receives a call, it is "paged," replies to the page, and is assigned a voice channel on members of the same set of data channels. Once a call is established on a voice channel, the hand-off process functions to maintain service quality.

As a mobile unit travels through a cellular system, its signal strength is periodically measured as part of the location process. A system control algorithm is then applied to determine at what point a new radio path is better able to serve the unit, after which a data message is sent on the voice channel to the mobile directing it to tune to the new channel. The data message and subsequent retuning are initiated on the voice channel using a "blank and burst" process. In a few 10ths of a second, voice transmission is blocked and a digital burst of data is transmitted or receiv- ed. The forward or cell site-to-mobile unit message is re- peated eleven times, while the reverse or mobile-to-cell site message is repeated five times. The repetitions are necessarry to ensure error free reception during the hand-off process to avoid disconnections. The precise synchronizations required in this process are fulfilled by a main computer in the MTSO and four control microprocessors: one in the data link that provides the signaling path between cell sites and MTSO, two in the cell site (one is a backup unit), and one in the mobile unit.

In a cell site, the number of separate frames is a function of the number of channels assigned for a particular cell's use. Operational control of all frames is maintained with hard-wired logic and programmable controllers (microprocessors). As equipment installation at each cell site was completed, its integration into the system was checked using specially equipped service test vehicles (STV's) and a computerized mobile telephone laboratory (MTL). Both types of vehicles would place calls, institute hand-off procedures, and record system performance. Tests focused on data transmissions required to receive and to place a call - paging and access proficiency, respectively. Upon completion of integration tests, overall system quality control tests were begun in January 1978.

In system quality control tests, 100 Bell employees received mobile units for testing hand-off control algorithms. Exhibit C-4 lists cell site locations, their abbreviations, and corresponding antenna heights and illustrates predicted coverage areas of each cell site.

The control algorithm in actual usage must follow the designated coverage patterns to maintain adequate coverage within each cell. The number of channels assigned to each cell site is a function of predicted traffic patterns and overlapping coverage. Exhibit C-5 shows the modified hexagonal cell patterns and lists the voice channel assignments for each cell site. Using the mobile telephone laboratory (MTL) and service test vehicles (STV's), coverage patterns were verified within reason with one notable exception. The Canal Street site, with antenna height of 550', was consistently perceived as the strongest signal outside its assigned coverage area. Original setup of voice communications would

occur through the Canal Street cell site, only to be immediately handed off to the appropriate cell site by the MTSO central computer according to the control algorithm. To alleviate this problem, test engineers experimented with lowering the signal power used at the Canal Street site. Reducing the signal power 10dB resolved the Canal Street problem. The control algorithm maintained voice transmission with a minimum number of hand-offs.

Another quality test examined perceived voice quality of a stationary phone versus the mobile phone. In tests measuring interference and Rayleigh fading,* stationary and mobile reception were compared by driving a vehicle along a test route originating at the Lake Zurich (LKZ) cell site. In Exhibit C-6 the dashes represent areas on the test route where the mobile unit received an inadequate signal, while the X's indicate where the stationary unit received an inadequate signal. As shown, the mobile unit received a better signal than a stationary unit at the perimeter of the service area. The transmission power of the outer cell sites was reduced 6dB and the voice quality was equalized for both the stationary and mobile units. Equal quality of transmission for both stationary and mobile units is necessary to maintain customer satisfaction. It would be an inconvenience for the mobile customer to have to shout to be heard, while the other party could speak in a normal tone of voice. Voice equalization eliminates the possibility of such a situation occurring.

One of the final quality tests was to determine the number of calls per second the system could handle efficiently. This was tested by placing mobile-to-mobile calls using computerized facilities of the MTL. Exhibit C-7 is a graph summarizing the data obtained. The transmission success rates obtained were very reasonable, ranging from 40% for 6 calls per second to 98.1% for 1 call per second. The intermediate tests were complete, and Frank Blecher and the other engineers at Bell Labs involved with the project were pleased with the results. "Call setup and handoff algorithms had been thoroughly exercised and found to be satisfactory, and the system operated very well in terms of both call control and quality of voice frequency transmission," said Blecher. Now the marketing and service tests could begin as early as December 1978.

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*Rayleigh fading occurs on received signals at both stations as the mobile unit moves through an interference field made of many waves which arrive with different amplitude and phase.

Systems Marketing

During installation and service testing, several thousand inquiries about the mobile phone service were received from such widely varying interests as law firms, contractors, and wrecking services. To verify the results of previous market research and develop a better estimate of marketability, a sales test was conducted. Prospective customers were randomly selected and offered service as mobile units became available. A high capacity installation and service center was built in Elmhurst, IL in preparation for the commercial service test. A delay was encountered as suppliers of mobile units were behind in their production schedules. The E.F. Johnson Co., Motorola, and OKI, Inc. were contracted to supply mobile units, as AT&T was prohibited by the FCC from marketing its own terminal equipment. This provision was made to allow other firms entry into the cellular field. It was anticipated that about 1,400 subscribers would be using the trial system by the end of 1979, and within the year approximately 2,000 units were installed.

Of the selected businesses, approximately 12% purchased the new service. Sales were hindered by the demonstration nature of the program, which could not guarantee continued service beyond January 1, 1980. Among the customers using AMPS, a survey was made to evaluate their opinions of the service. Of the choices, 75% responded "very satisfied", 25% responded "somewhat satisfied", and one responded "unsatisfied". The 25% who were "somewhat satisfied" cited cost as their major complaint.

Charges for service included a base fee of $25 a month for two hours of calls and 25 for every minute thereafter. These fees are exclusive of equipment rental, which was $45 or $60 a month depending on the style of equipment selected. Such costs are beyond most private users, but within reason for most businesses since over 50% of the businesses using the service reported improved productivity. Cellular systems can therefore reliably provide all services of a stationary telephone network. Exhibit C-8 displays the normal and terminal events and the percentage of their occurrences. In current systems, less than 50% of mobile-initiated calls received voice channel assignments on the first attempt.

As of August 1982, AMPS in Chicago is still functioning as a limited demonstration program. After Bell Labs' application for Chicago was first rejected by the FCC, AT&T reduced the number of units involved, which didn't affect the project for the trial. In keeping with this reduction, the FCC limited service to a maximum of 2500 units. The future of all cellular radio systems is being decided by the rulings of the FCC. Licenses allocating radio frequency spectrum will be issued in such a manner as to pro- mote efficient, rapid growth of nationwide cellular service.

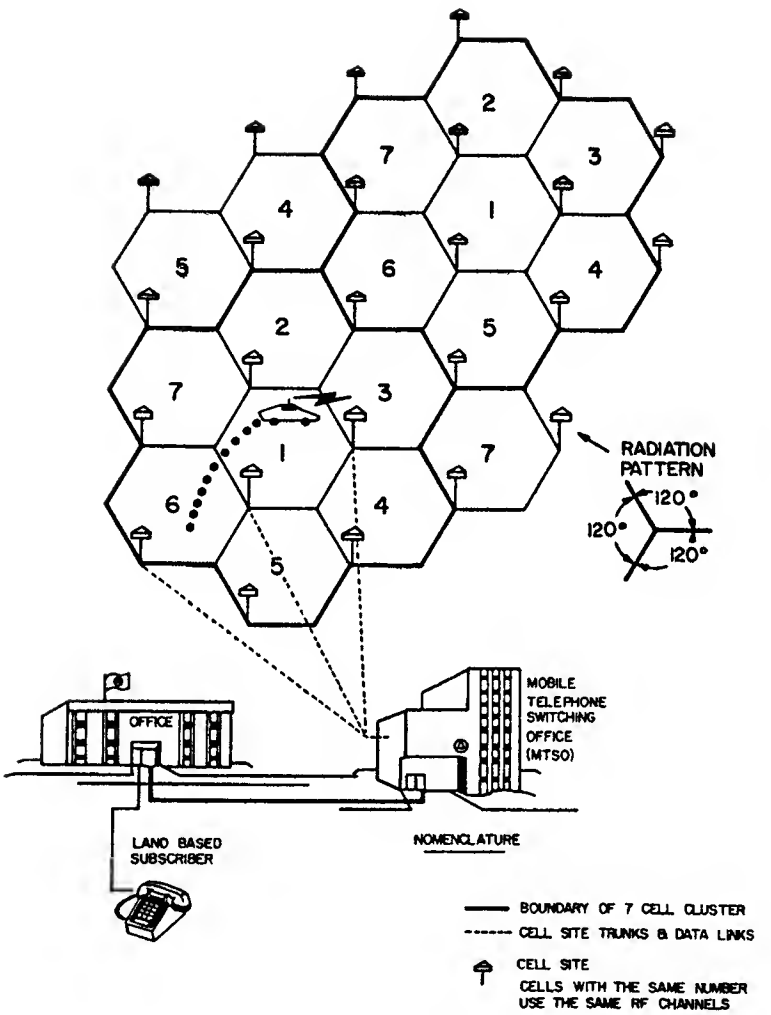
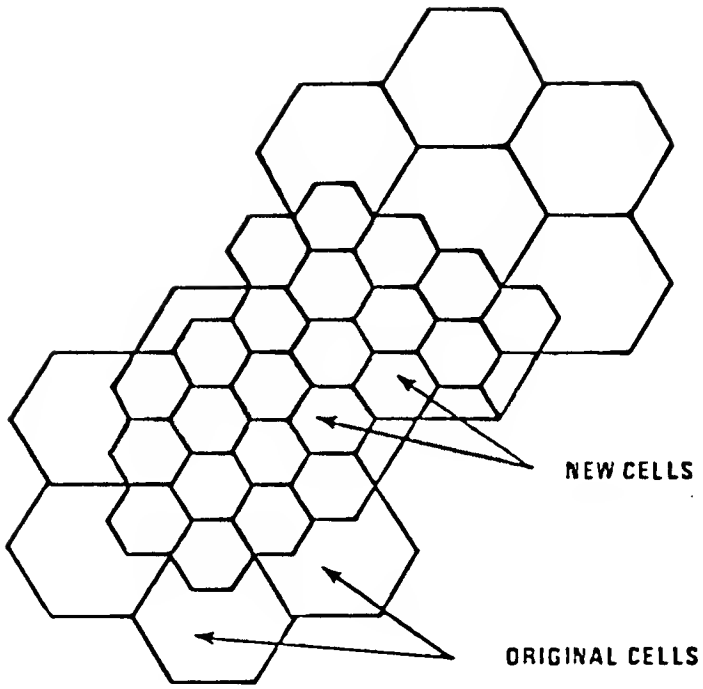
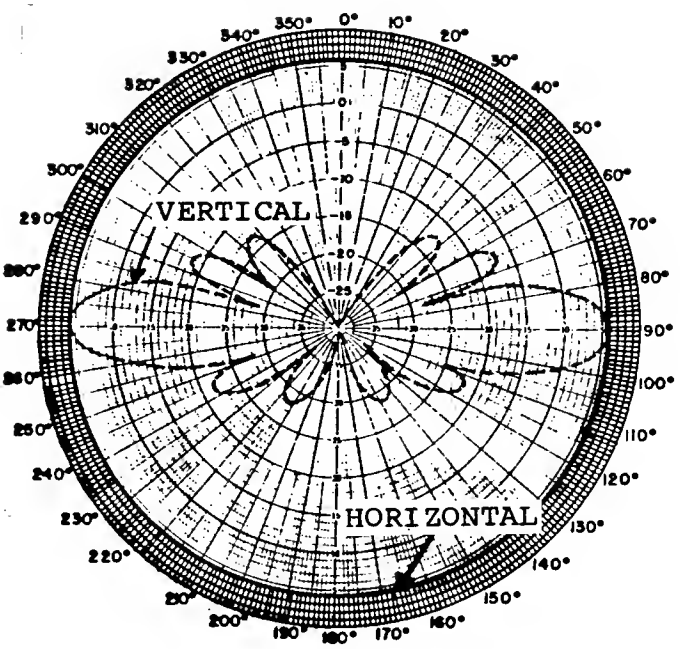


Exhibit C-1, Mature Cellular System



Cell Split Is Applied Only
To The Busiest Cells

Exhibit C-2, Realistic Cell Splitting Pattern



Omnidirectional land site antenna radiation pattern (0 dB corresponds to the reference half-wave dipole gain).

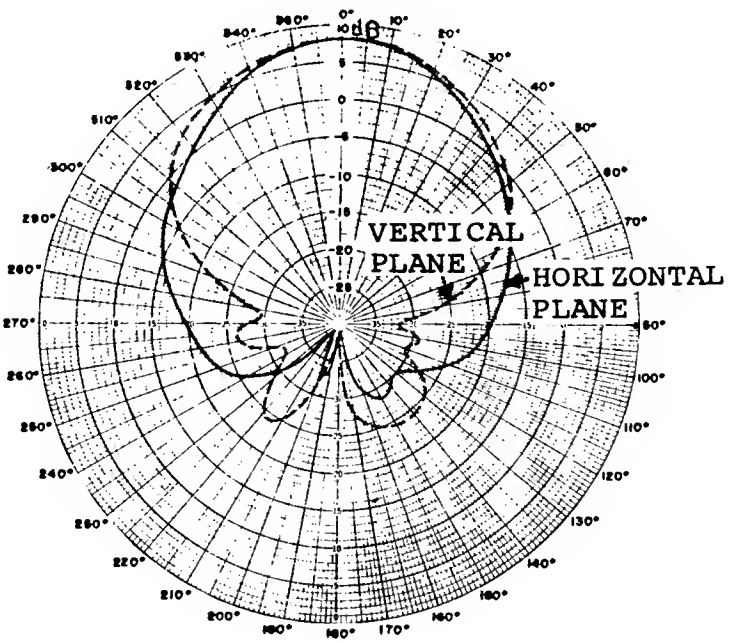
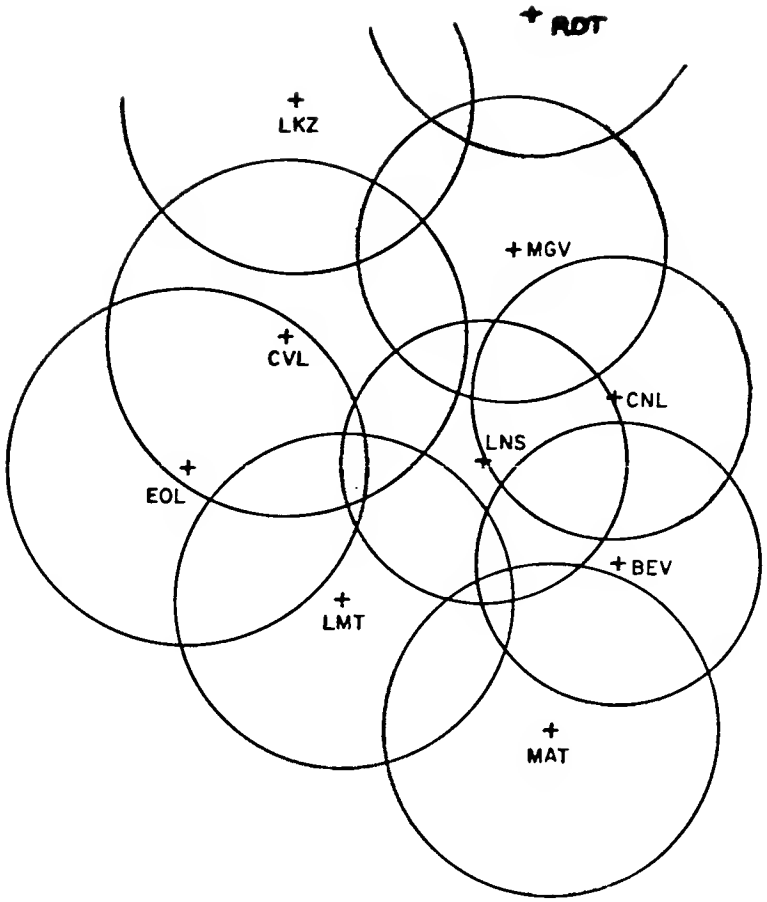


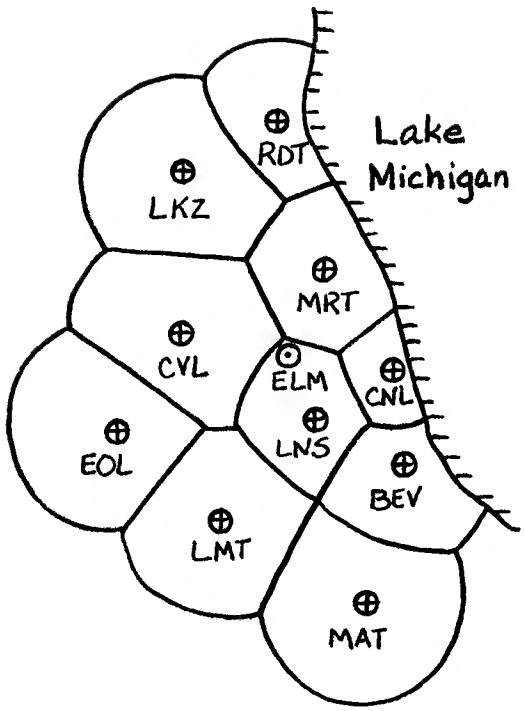
Exhibit C-3, Omni- and Uni-Directional Antenna Patterns



CELL SITE	ABBREVIATION	ANTENNA HEIGHT
Beverly	BEV	150'
Canal Street	CNL	550'
Cloverdale	CVL	325'
Eola	EOL	310'
Lake Zurich	LKZ	285'
Lemont	LMT	250'
Lyons	LNS	150'
Matteson	MAT	260'
Morton Grove	MGV	185'
Roundout	RDT	150'

Exhibit C-4, Predicted Coverage Areas and Cell Site Locations

The AMPS development system



There are ten cells in the Chicago developmental AMPS system, each one served by a separate cell site. The cell site provides coverage for about 2100 square miles of the metropolitan area.

Bell Labs engineers estimated that 136 voice channels would be needed to handle calls from the 2000 Chicago Service Test participants, with a 2-percent busy-hour blocking probability. The engineers divided the channels among the ten cell sites based on estimates of vehicular traffic distributions and expected customer calling patterns in each cell.

Federal Communications Commission regulations restrict the number of mobile units used in the developmental Chicago AMPS system. But reduced cell size and full use--and reuse--of the 666 available channels would allow AMPS to serve several hundred thousand units in a service area the size of Chicago.

Cell site	Voice channels	Cell site	Voice channels	Cell site	Voice channels	Cell site	Voice channels	Cell site	Voice channels
Beverly (BEV)	16	Cloverdale (CVL)	15	Lake Zurich (LKZ)	9	Lyons (LNS)	16	Morton Grove (MGV)	18
Canal Street (CNL)	26	Eola (EOL)	8	Lemont (LMT)	8	Matteson (MAT)	12	Rondout (RDT)	8

Exhibit C-5, Voice Channel Assignments

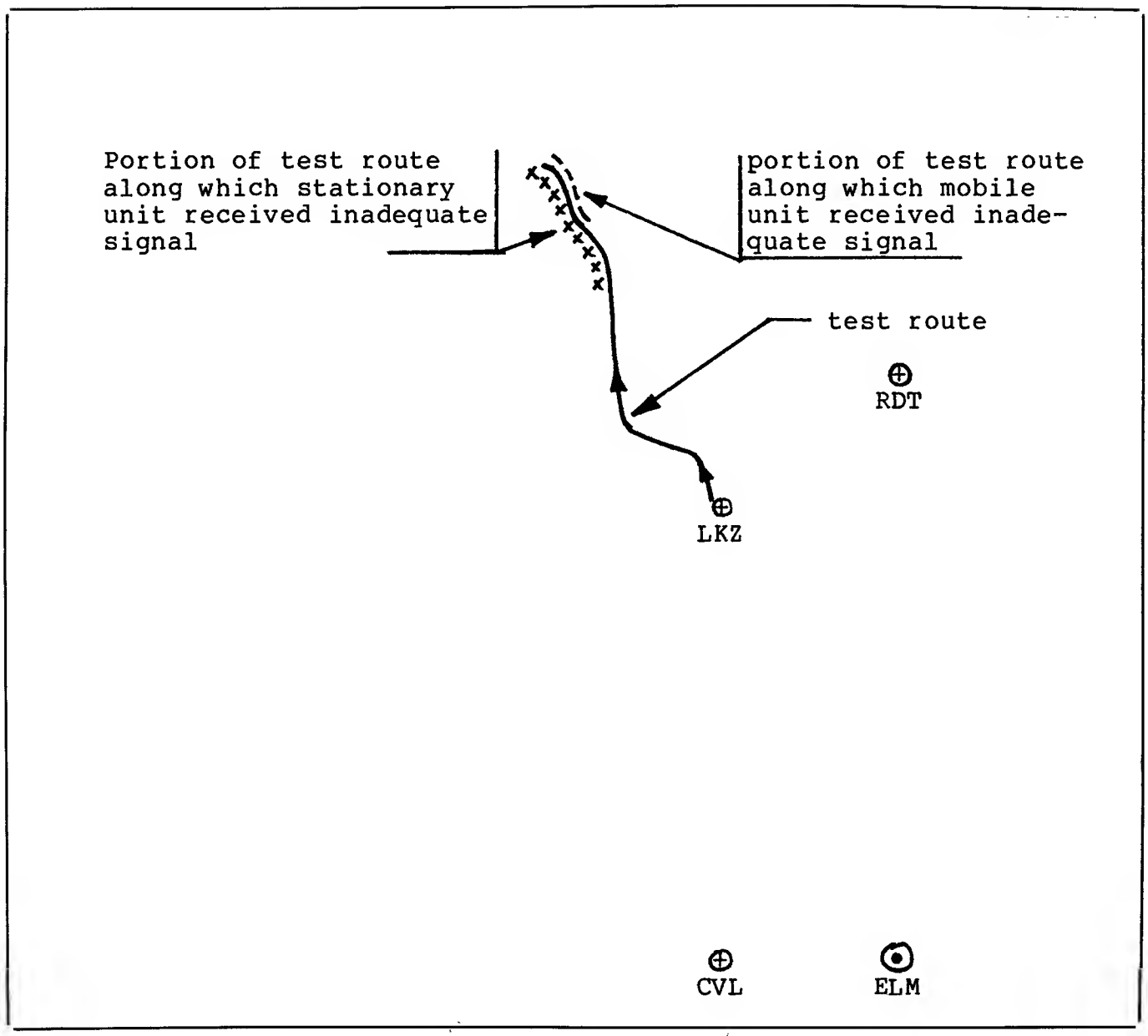


Exhibit C-6, Voice Quality Comparison

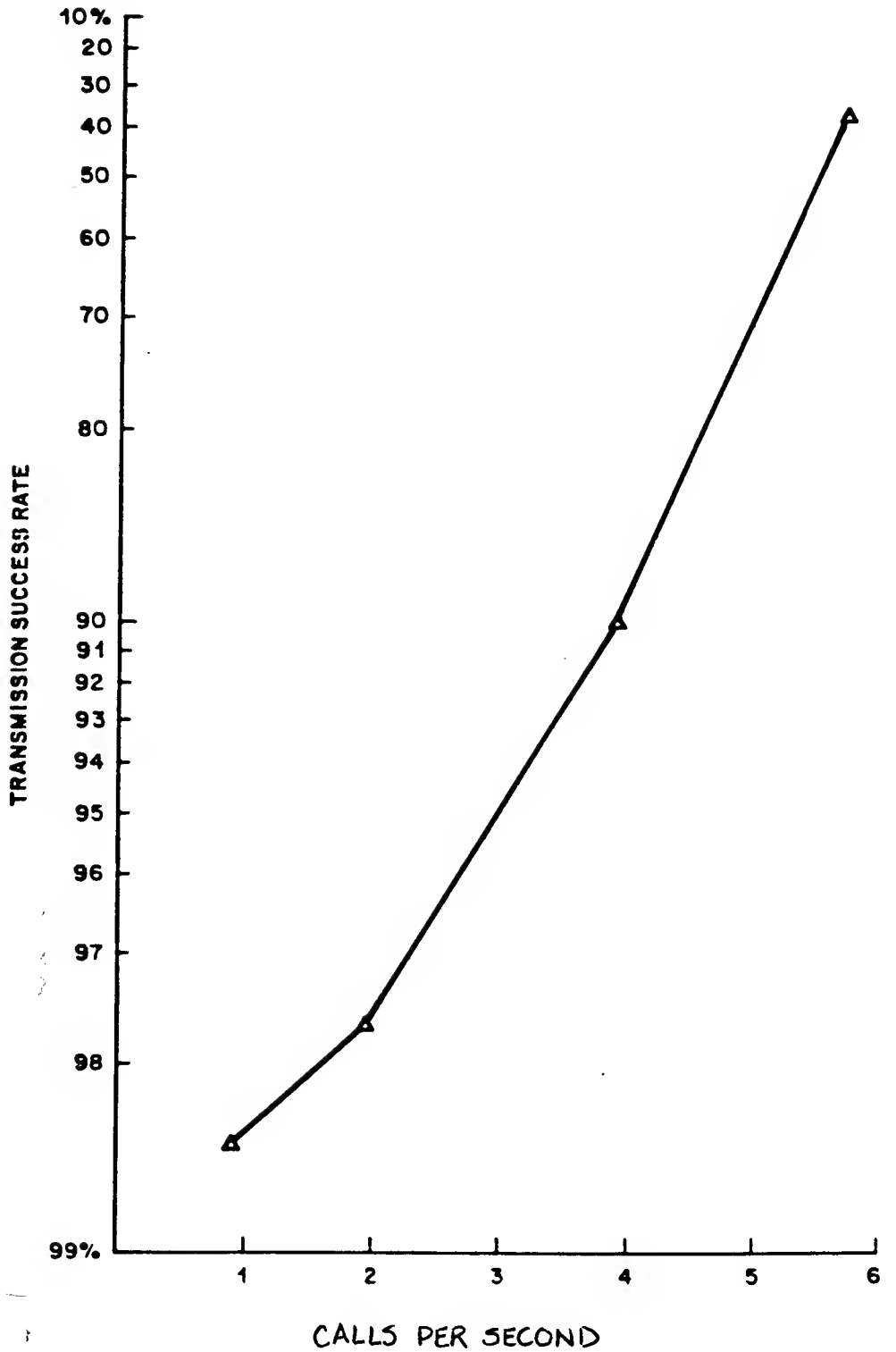


Exhibit C-7, Transmission Success Rate

MOBILE-INITIATED CALL ATTEMPTS

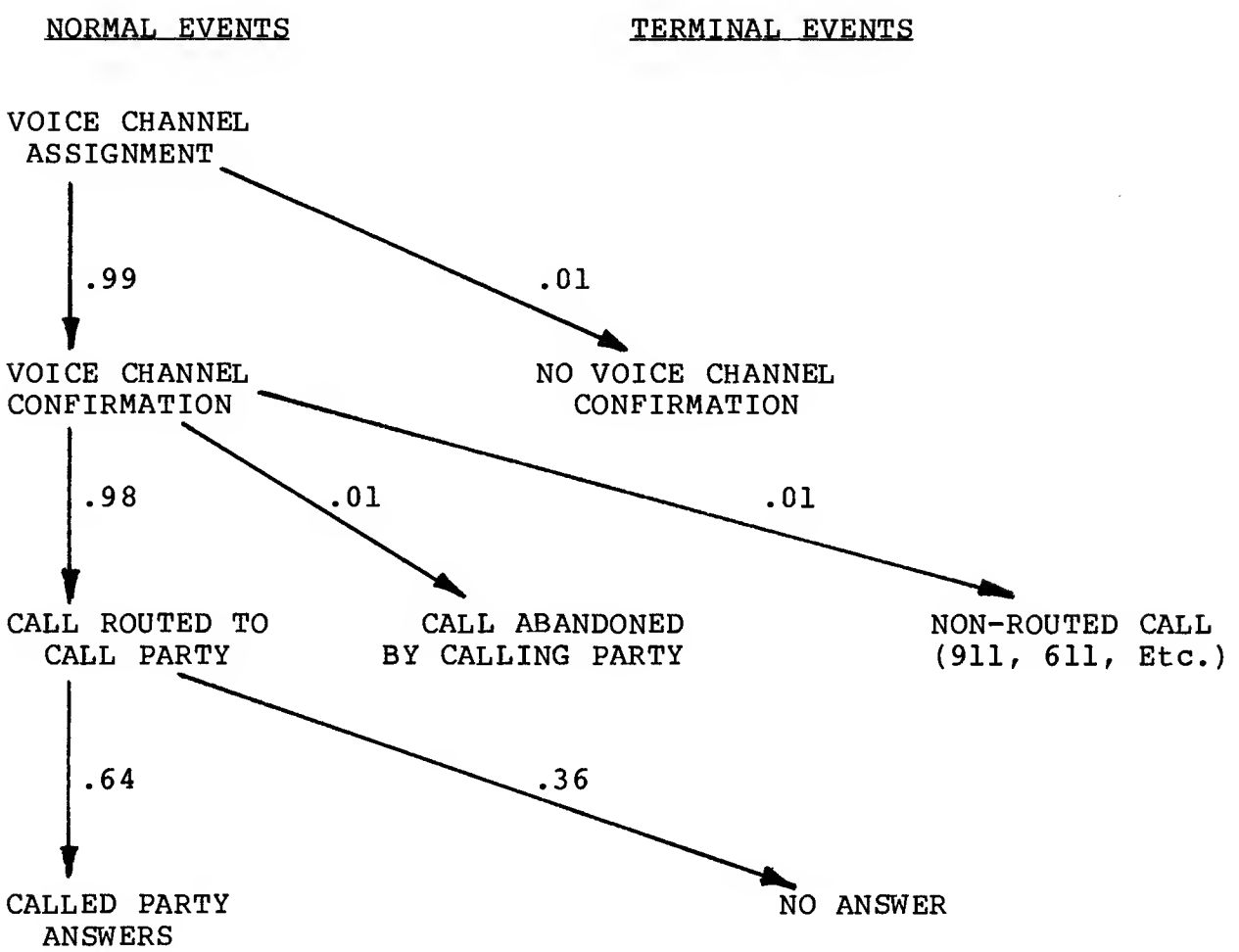


Exhibit C-8, Normal and Terminal Events for Mobile - Initiated Calls

PART D: ALTERNATIVE TO AMPS

Although AMPS has led the way in cellular development, the potential for substantial financial gains has attracted serious competition. A second demonstration program was licensed by the FCC in the Baltimore, Maryland - Washington, D.C. area. American Radio/Telephone Service, Inc. (ARTS) completed a limited demonstration program late in 1981. The ARTS cellular system covered 1800 square miles with eight cells and served approximately 200 customers. The size of the system was limited to avoid excessive losses if ARTS, Inc. was not granted a permanent license for the Washington-Baltimore area.

The equipment used in the ARTS cellular system was manufactured by Motorola. The Motorola designs are different than those used in the Chicago AMPS system, but are comparable from an overall system viewpoint. The basic cell site equipment, mobile units, and advanced switching and control network are ready for further commercial marketing. The basic equipment has been approved by the FCC, with the exception of Motorola's new portable, rechargeable phone. The eighth cell in the ARTS demonstration was included specifically to provide building penetration for the new handheld portable phone in Washington, D.C.

The ARTS system has proven its feasibility both technically and economically. It has also been estimated that interconnection with the public telephone network can be reasonably obtained by non-wireline companies. Illinois Bell Telephone, and a non-wireline company, American Radio/Telephone Service, Inc., the FCC has gained insight to aid its decisions regarding regulatory structure for nurturing cellular radio development nationwide.

PART E: BEYOND DEVELOPMENT - FCC HANDS DOWN REGULATORY ORDERS FOR LICENSING

In the spring of 1982, the FCC released and began defense of its regulatory structuring. A major source of conflict is the "set aside," which reserves a 20MHz allocation for telephone companies with another 20MHz allocated to all others interested in offering cellular service. This "set-aside" has been limited to a two-year duration, after which any entity may apply for either 20MHz band. To encourage more rural development, no limits have been placed on the number of markets a company may enter. Furthermore, no limits have been placed on resale of cellular service to allow limited entry into the market without a license. Exhibit E-1 is a brief statement issued by three commissioners of the FCC defending the "set aside."

As the "set aside" may be brought to court, background information on the FCC in previous court cases is included. The following quotations from court cases involving the FCC (although not cellular radio) indicate that anti-competitiveness is not the main concern of the FCC.

> Hawaiian Telephone Co. vs. FCC (1974) - "Were the Commission to base its action solely on the ground that competition in the industry would be favored thereby and nothing more, we would have serious doubts as to whether it had fulfilled its responsibility to consider other important criteria before determining whether its proposed ruling is in the public interest."
>
> U.S. vs. FCC (1980) - The court continued, "The agency's determination about the proper role of competitive forces in the industry must therefore be based, not exclusively on the letter of the anti-trust laws, but also on the special considerations of the particular industry."

The FCC was not blind to the prosecution of American Telephone & Telegraph. To prevent subsidization of cellular service from revenues of the protected public telephone service, the FCC permitted AT&T entry into the cellular market only through an entirely separate subsidiary. AMPS is AT&T's subsidiary through which applications for cellular licenses have been made. The FCC requires telephone companies to offer interconnections to the public telephone network to both their own operations and non-wireline carries.

AT&T has announced tentative plans to rename AMPS as ATT Cellular Inc., and to separate it into two divisions: Systems and Service. ATT Cellular Systems would sell and install cellular systems while providing managerial and technical advice. ATT Cellular Services would be a supplier of service within areas for which it receives licenses to operate from the FCC. AMPS, or ATT Cellular, Inc., will have access to the research support of AT&T until September 1, 1987, and longer, depending on the court ruliings concerning the divestiture of AT&T.

The June 7, 1982 application deadline for cellular service of the 30 largest Standard Metropolitan Statistical Areas (SMSA) found the FCC swamped in paper. Cellular Systems, Inc. a subsidiary of Graphic Scanning Corp. (operator of the largest paging service in the U.S.), submitted applications for all 30 markets. The applications were so bulky they needed two semi-trailers for delivery. The FCC encouraged all applicants to reach mutually satisfying agreements among themselves to avoid the lengthy comparative hearing process used by the FCC in issuing licenses. In this process all applicants for cellular licenses in one city would assemble and be required to answer any questions the FCC commissioners would have. After the hearings, the commissioners would decide which party should be granted a license.

Local telephone companies were more successful in negotitating joint ventures, as evidenced by 52 applicants for 30 slots, while non-wireline applicants numbered 142 for their 30 slots. AT&T reached agreements with 19 companies in the 29 areas where it applied for cellular radio licenses. The AMPS subsidiary will be majority owner in 23 markets, while GTE will be majority hold in 6 areas and sole wireline applicant in Tampa, Florida. Exhibit E-2 summarizes the non-wireline applicants as compiled by the FCC.

The application deadline for the 30 next largest SMSA's is November 8, 1982. A similar deluge of applications is expected by the FCC. Each application cost more than $100,000 to prepare these technically and legally substantial documents. The quantity of applications received speaks clearly of the financial benefits from cellular service.

Many questions on licensing remain unanswered by the FCC. For example: 1) What design features will be considered more favorably in a cellular system - wide area coverage or centralized intensive service?; 2) When will licenses be granted?; and 3) Will telephone companies receive their licenses first, since there are fewer to evaluate? These questions bring up serious problems. For example, if the telephone companies are licensed first, they could conceivably capture the market and eliminate competition. AT&T's and GTE's agreements on operation of cellular systems, though encouraged by the FCC, have attracted the attention of the

Justice Department's Antitrust division. Information requests were served on the telephone companies on July 7, 1982. These requests are viewed as routine fact-finding inquiries.

The FCC has struggled with regulation of cellular radio for over a decade. Michael Sullivan, an FCC attorney, said that the need to bring cellular radio into early service outweighed any possible anti-competitive considerations raised by its method of awarding licenses. A major question is how the FCC will award licenses. There is a great deal of speculation as to whether comparative hearings will be held or whether the FCC will turn to a lottery approach to speed up the process. Exhibit E-3 is an article from Business Week which argues the pros and cons of the lottery approach.

Whatever approach the the FCC takes on licensing, those companies not awarded licenses will probably protest. Considering that financial experts predict revenues from the top 30 SMSA's to approach $3 billion by 1987, competition for any share of the cellular market will be fierce.

SEPARATE STATEMENT OF COMMISSIONER JOSEPH R. FOGARTY
IN WHICH COMMISSIONERS JAMES H. QUELLO AND ANNE P. JONES JOIN

In Re: Notice of Inquiry and Notice of Proposed Rulemaking--Cellular Communications Systems.

The Commission has already firmly determined that the implementation of cellular service nationwide is technically feasible and highly desirable from the standpoint of consumer interest. We therefore should be moving as expeditiously as possible to provide the necessary regulatory framework so that this great potential service may become a marketplace reality. In this regard, I am pleased that this Notice is sufficiently broad to allow the Commission to promulgate the necessary regulatory structure and requirements at the end of one comment period.

The Commission's Notice properly identifies nine issue areas for comment (i.e., market definition, competitive systems within a market, eligibility, equipment, resale, jurisdiction, competing applications, technical standards, and spectrum allocation). In this regard, I recognize that the Court of Appeals decision in NARUC v. FCC, 525 F.2d 630 (D.C. Cir. 1976), necessarily implicates questions of competition in many of these areas. At this point, however, I am equally concerned that the potential benefits of wireline carrier participation in the provision of cellular service, which the Commission has previously identified, not be ignored. In its Second Report and Order in this proceeding, the Commission specifically found that important benefits of technical expertise, access to capital, and nationwide compatibility would attend participation by wireline carriers in the provision of cellular service. This Notice is clearly structured to provide an appropriate vehicle for assessing and determining these critical trade-offs.

A final concern I have relates to whether wireline carriers should be permitted to manufacture, supply, and maintain mobile equipment used in cellular systems and, if so, whether such offering should be allowed on a tariffed as well as non-tariffed basis. In this connection, while the provision of mobile equipment on a competition basis is consistent with Commission policies in the field of terminal equipment generally, I believe the Commission should examine whether or not the consumer should be free to obtain mobile equipment from a carrier on a tariffed basis. The high cost of mobile equipment might make such a tariff option extremely attractive to many users.

Cellular mobile telephone services is an exciting concept, and I am confident that the Commission will be able to expedite its consideration and decision in this proceeding so that the American people will soon have the full benefits of this significant technology.

...WHILE MULTIPLE NON-WIRELINE APPLICATIONS GUARANTEE COMPARATIVE HEARINGS

Here is a list by city, compiled by the FCC, of where non-wireline company applications were filed:

ATLANTA: Gencom, Celcom Communications Corp. of Georgia, Unity Telecommunications Systems Inc., Maxicom Inc., and Cellular Mobile Systems of Georgia Inc.

BALTIMORE: Cellular Mobile Systems of Maryland Inc., American Radio Telephone System Inc., MRTS of Baltimore, Metro Phone Associates, and Post Cellular Telecommunications of Maryland Inc.

BOSTON: Yankee Telecom Corp and Cellular Mobile Systems of Massachusetts Inc.

BUFFALO: Western Union, Celcom Communications Corp. of Buffalo, and Cellular Mobile Corp.

CHICAGO: Michael & Eileen Ice, Rogers Radiocall Inc., and Cellular Mobile Systems of Illinois Inc.

CINCINNATI: Midwest Mobilephone Corp., Metro Mobile CTS, Cellular Mobile Systems of Ohio Inc., Cellular Communications of Cincinnati Inc., and R.L. Plessinger dba Miami Valley Radiotelephone, and Carpenter Radio Co.

CLEVELAND: MCI Cellular Telephone Co., Cellular Mobile Systems of Ohio Inc., Cellular Communications of Cleveland Inc., Cleveland Mobile Telephone Inc., and Carpenter Radio Co.

DALLAS: D/FW Signal Inc., Lin Cellular Communications Corp., Cellular Mobile Systems of Texas Inc., Mid-America Cellular Systems Inc., and MCI Cellular Telephone Co.

DENVER: Metro Mobile CTS, McCaw Communications of Denver Inc., Cellular Mobile Systems of Colorado Inc., MCI Cellular Telephone Co., and American Radio Telephone Communications of Colorado.

DETROIT: Post Cellular Telecommunications of Michigan Inc., Celcom Communications Corp. of Michigan, Unity Telecommunications Systems Inc., Cellular Mobile Systems of Michigan Inc., and American Radio Telephone Communications of Michigan & Ohio.

HOUSTON: Houston Cellular Corp., Metro Mobile CTS, Lin Cellular Communications Corp., American Radio Telephone Communications of Houston & Gulf (joint venture), Cellular Mobile Systems of Texas Inc., Cellular Systems Inc., MCI Cellular Telephone Co., and Charisma Communications Corp. of the Southwest.

INDIANAPOLIS: Midwest Mobilephone Corp., Westel-Indianapolis Co., Cellular Mobile Systems of Indiana Inc., and Carpenter Radio Co.

KANSAS CITY: Western Union, McCaw Communications of Kansas City Inc., Metro Mobile CTS, Cellular Mobile Systems of Missouri Inc., Mid-America Cellular Systems Inc., and MCI/Mobile Radio Communications.

LOS ANGELES: Los Angeles Cellular Corp., Lin Cellular Communications Corp., Cellular Mobile Systems of California Inc., and ICS/MCI (partnership).

MIAMI: Cell-Tel Network, Metro Mobile CTS, Cellular Telephones of Florida Corp., Florida Cellular Telephone Co., MCI Cellular Telephone co., Unity Telecommunications Systems Inc., Maxicom Inc., MRTS-Poe of Miami, Charisma Communications Corp. of America, Cellular Mobile Systems of Florida Inc., and American Radio Telephone Communications of Florida.

MILWAUKEE: Cellular Mobile Systems of Illinois Inc. and Westel-Milwaukee Co.

MINNEAPOLIS: Metro Mobile CTS, Cellcom Inc., MCI Cellular Telephone Co., and Cellular Mobile Systems of Minesota Inc.

NEW ORLEANS: Western Union, Radiotelephone Inc., Mid-America Cellular Systems Inc., and Cellular Mobile Systems of Louisiana Inc.

NEW YORK: Cellular Systems Inc., Lin Cellular Communications Corp., Celcom Communications Corp., and Cellular Mobile Corp.

PHILADELPHIA: Cellular Mobile systems of Pennsylvania Inc., Celcom Communications Corp. of Pennsylvania, Unity Telecommunications Systems Inc., Automatic Wide Area Cellular Systems Inc., and MCI Cellular Telephone Co.

PHOENIX: Gencom, Metro Mobile CTS, and Cellular Mobile Systems of Arizona Inc.

PITTSBURGH: Celcom Communications Corp. of Pittsburgh, Cellular Mobile Systems of Pennsylvania Inc., and MCI Cellular Telephone Co.

PORTLAND: Interstate Mobilephone Co., Parr Communications Co., American Radio Telephone Corp. of Washington and Oregon, Cellular Mobile Systems of Washington Inc., and MCI Cellular Telephone Co.

ST. LOUIS: Metrocom of St. Louis, Cellular Mobile Systems of Missouri Inc., and Cybertel-Cox Cellular.

SAN DIEGO: Gencom, Metro Mobile CRS, and Cellular Mobile Systems of California Inc.

SAN FRANCISCO: Instrastate Radio Telephone Inc. of San Francisco, Cellular Mobile Systems of California Inc. McCaw Communications of San Francisco Inc., and Cellular Netork Inc.

SAN JOSE: California Celcom Communications, Intrastate Radio Telephone Inc. of San Francisco, Cellular Mobile Systems of California Inc., Cellular Network Inc., and McCaw Communications of San Jose Inc.

SEATTLE: Interstate Mobilephone Co., Cellular Mobile Systems of Washington Inc., and American Radio Telephone Communications of Washington and Oregon.

TAMPA: Gencom, Cellular Telephone of Florida Inc., Metro Mobile CTS, Celcom Communications Corp. of Florida, Westel-Tampa Co., Florida Cellular Group (joint venture), MCI Cellular Telephone Co., Unity Telecommunications Systems Inc., Maxicom Inc., MRTS-Poe of Tampa, Charisma Communications Corp. of Florida Inc., and Cellular Mobile Systems of Florida Inc.

WASHINGTON, D.C.: American Radio Telephone Service Inc., Post Cellular Telecommunications Inc., MRTS of Washington, Metro Phone Associates, and Cellular Mobile Systems of The District of Columbia Inc.

Exhibit E-2, Summary of Non-Wireline Applicants

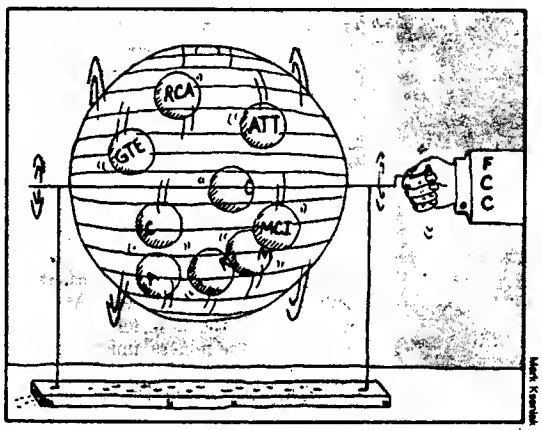
COMMENTARY By Larry Kahaner and Anthony Durniak

The dangers of letting Lady Luck award FCC licenses

The radio spectrum may be invisible to the human eye, but it is a finite natural resource like land or water. Managing it is the responsibility of the Federal Communications Commission, which grants licenses to use chunks of this valuable radio frequency for operating television and radio stations, telephone systems, satellites, and other communication networks. Now the FCC is about to change the way in which it issues these licenses.

Instead of holding lengthy hearings to examine the relative merits of each applicant for a license, the FCC—after 10 years of studying the issue—has asked for and is expected to get congressional approval for its plans to divvy up the radio spectrum by holding lotteries. The commission could conduct its first lottery by the end of the year. Most communications companies welcome the lottery concept because it promises to speed up the licensing process. But such lotteries carry the potential for creating new problems as well.

Streamlined procedure. The lottery will undoubtedly make the FCC's job easier by freeing the growing logjam of applications. Because there are limited amounts of radio frequency, the FCC has had to restrict the number of operating licenses that it grants. The process is easy when there are 15 qualified applications for 15 frequency slots, for example, but this kind of balance is rarely the case. Because of the agency's recent move toward encouraging competition in communications, hordes of companies have deluged it with truckloads of documents in their quest for operating licenses. In the past year, the FCC received 6,000 applications to operate low-powered TV transmitters—stations that have limited range and are intended to serve only the local community. And 200 applicants are competing for about 60 licenses to offer a new mobile telephone service called cellular radio.



Lottery: New way to pick a winner.

By shortening the licensing process, the lottery also promises to bring new technologies to the public faster. Comparative hearings now delay new communications services from reaching consumers by an average of three years—a delay that often gives investors second thoughts. The lottery, declares Mark S. Fowler, chairman of the FCC, "is the best way to get service out fast to the people."

The lottery system is not used widely by the government, so the FCC pioneers will have no model from which to learn the potential pitfalls. Inherent in converting to a lottery is the temptation for commissioners to abrogate their responsibility for choosing the most technically qualified and financially stable company to provide a public service. "The commission should not deceive itself into believing that the use of a lottery is the panacea that will eliminate the tough administrative decision-making processes that licensing demands," the National Association of Broadcasters has warned the FCC.

Indeed, without the rigorous examination of petitioners, a lottery could lead to speculative use of the radio spectrum. The current licensing system helps to weed out obvious speculators, since it forces applicants to invest in making detailed cost and technology projections. Rather than operating a communications service, these gamblers want instead to get a license to resell it to someone else at a considerable profit. The FCC acknowledges that the lottery will increase the odds that speculators will win licenses.

This problem would be exacerbated by a second FCC proposal that would shorten the period required between the time a license is awarded and when it could be sold. "We are concerned about filing mills—firms that will file at every proceeding for clients who don't intend to serve the public," says attorney Edward Hayes, who represents the National Association of Black-Owned Broadcasters before the FCC. Speculation, he adds, "will only increase the paperwork problem."

In its worst form, the proposed lottery could conceivably drag out commission proceedings longer than comparative hearings do now. Because present applicants expect to be challenged at these proceedings, they come prepared to describe their qualifications in fine detail. The mechanics of the lottery have not yet been worked out, but it is likely that the FCC will determine whether the winner is qualified only after its name has been drawn. If the applicant picked is found not to be qualified, the commission would begin the lottery process all over again. Under this method of selection, applicants could prolong matters by waiting until they win the lottery to assemble the detailed documentation that they would need to prove their qualifications.

Minority view. Ironically, many minority broadcasting groups—the very people who the FCC believes will be helped most by the lottery—think it may backfire. FCC Chairman Fowler maintains that minorities can least afford the long, expensive hearings. The minority broadcasters counter that a lottery ignores the value of their proposed community service. For their applications to have meaning, they say, they must fight it out against opponents in a public forum.

The FCC's desire to streamline the process for such applicants is being encouraged by Congress and most of the communications industry. They are all waiting, however, to see how the FCC will overcome the lottery's potential drawbacks. "All the new services coming along, especially low-powered TV, make a lottery imperative," says James J. Popham, counsel for the National Association of Broadcasters. But, he cautions: "Whether this will actually speed up the process at the commission will depend upon how it is implemented."

BUSINESS WEEK: July 26, 1982

Exhibit E-3, Pros and Cons of the Lottery Approach (reprinted from July 26, 1982 issue of Business Week by special permission (c) 1982 by McGraw-Hill Inc.)

REFERENCES

1. FCC Docket No. 18262 which included all documents released by the FCC on cellular policy.

2. Developmental reports issued by AMPS, Inc. every 90 days during the Chicago Trial.

3. Draft paper released by AMPS, Inc. titled, "Advanced Mobile Phone Service System Description" dated July 15, 1982.

4. Demonstration and interview with Norman Bach of Motorola on the American Radio/Telephone Service here in Washington, D.C.

5. Interview with Jerry Stover of Communications Industries in Dallas, Texas on the viewpoint of non-wireline applicants.

6. Information published by J.T. Kennedy of Bell Laboratories.

7. "U.S. Begins Car Phone Inquiry," New York Times, July 8, 1982.

8. "Gold Rush at the FCC," by John W. Dizard, Fortran, July 12, 1982.

9. "Advanced Mobile Phone Service," by Franklin H. Blecher, IEEE Transactions on Vehicular Technology, Vol. VT-29, No. 2, May 1980.

10. "Cellular System Expands Number of Mobile-phone Channels," by Harvey J. Hinden, Electronics, May 24, 1979.

11. "Mobile Phone Service Moves Ahead," by Duane L. Huff and Raymond J. Pennotti, Bell Laboratories Record, March 1980.

12. Insight gained by reading Telephone News, which is a weekly trade publication. Current topics in management, marketing, and regulations are included.

INSTRUCTOR'S NOTES

This case study was written to show the evolution of a new technology and its relation to government regulation. Cellular radio is especially interesting as it raises many technical as well as policy issues. The following questions can be used as starting points for class discussion.

PART A:

1. What type of equipment would be needed to implement a cellular system?

PART B:

1. What type of propagation characteristics does the 800 MHz region have?

2. What makes the 800MHz suitable for use in a cellular system?

PART C:

1. What factors should be taken into consideration when choosing an antenna configuration?

2. What can be done to alter antenna pattterns for more favorable coverage?

3. What kind of control problems could occur which would be handled by the control algorithm?

4. What type of test procedure could be used in voice quality comparison tests?

5. Why was the demonstration in Chicago limited in its expansion of service?

6. What different regulations would be in effect for developmental and permanently licensed systems?

7. Can information seem more favorable by careful use of graphics (Exhibit C-7)?

PART D

1. What is the advantage of having two comparable, but different systems available?

2. What kind of insight was the FCC looking for by licensing developmental systems?

PART E:

1. Will speedy licensing of cellular radio be hindered by an over-abundance of paper?

2. Will budget cuts and reduced staff force the FCC to turn to a lottery approach to solve its licensing dilemma?

3. Considering that the Japanese have a commercial cellular system in Tokyo, which has been serving over 10,000 customers since 1980, has the FCC been too slow in opening the cellular market in the U.S.?

As of August 1982, no licensing had been granted by the FCC. No information is forthcoming as to when licensing will take place, but questions may be referred to:

FCC - Common Carrier Division
1919 M Street, N.W.
Washington, D.C. 20554

Public Information Number (202) 632-7000.